Implementing a Low-Cost Spatial Light Modulator

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Spatial Light Modulator

A spatial light modulator [SLM] is an optical device which can modify the amplitude, phase, and/or polarization of a coherent light beam. SLMs can produce structured beams with "designer" wavefronts, such as optical vortices, and have been applied to many fields of research and technology. Most modern SLMs use liquid crystals as the modulating material and hence are very similar to the LC displays found in many commercial products.

The Laser Teaching Center [LTC] recently purchased two low-cost Cambridge Correlators' SDE1024 SLMs for future use in a variety of optics projects by undergraduate and high school students. For this project, we illuminated the devices with a LM635 Collimated Laser Module from the same company, which emits a 24 mm diameter beam with λ = 635 nm. In the future, we hope to illuminate our SLMs with our argon laser (λ = 488 nm) to increase the obtainable phase range.

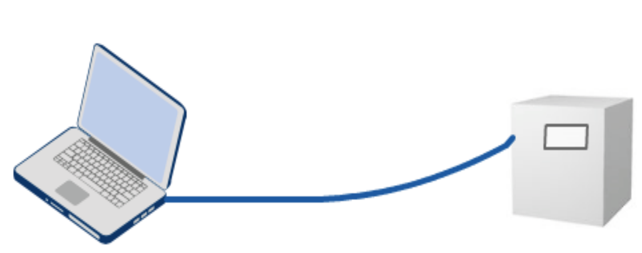
Specifications:

- Twisted Nematic (TN)
- Reflective-Liquid Crystal on Silicon (LCoS)
- Electrically-Addressed
- XGA resolution with 1024x768 9x9 µm pixels
- Bit depth: 8 bits [256 phase shift levels]
- Achievable phase range: 0.8π for red light

Programming the SLM

The display on the SLM was programmed by sending it a video signal from an auxiliary display port on the control computer. The transmitted XGA image was created using Paint or MATLAB, although a variety of graphics programs can be used.

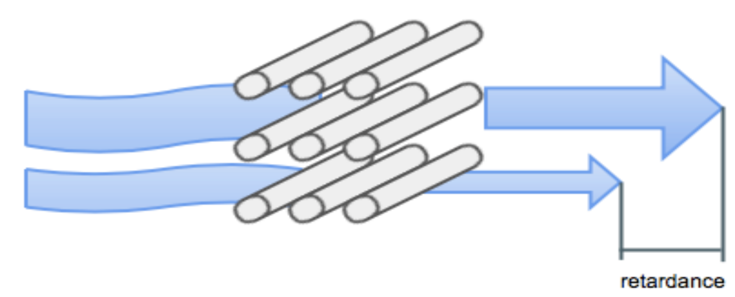
Transmitted white pixels [grey value 255] correspond to zero cell voltage, while transmitted black pixels correspond to the maximum cell voltage.



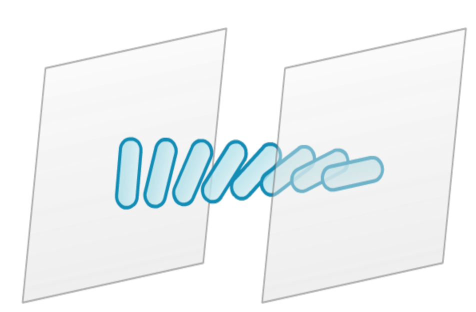
Properties of the SDE1024 SLM

Liquid crystals are rod-like molecules that occupy a state in-between liquids and solids.

They are birefringent meaning different polarizations of light can experience different indices of refraction.



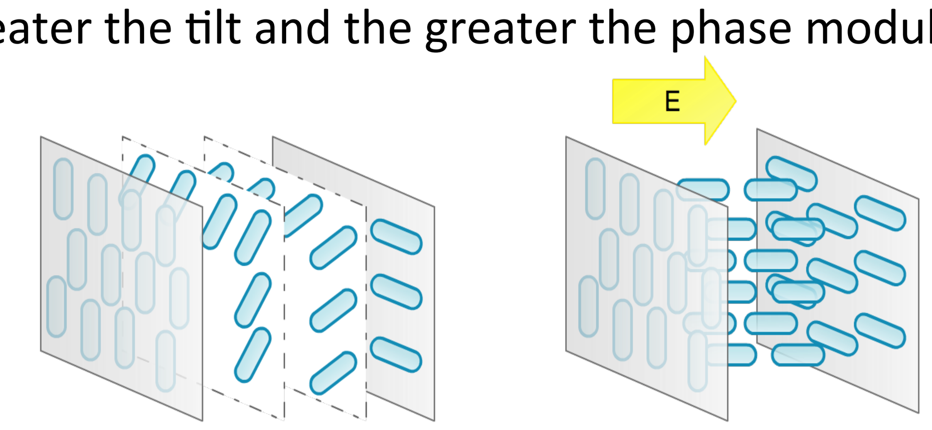
Liquid crystals can exist in a variety of configurations. One such configuration is *twisted nematic*. In TN mode the molecules are naturally twisted into a helix with the long axis of the front-most and back-most molecules usually being perpendicular. Because light is scattered along the axes of the molecules, the incident polarization follows the rotation of the helix.



The front and rear surfaces of the SLM cells are electrically conducting and are coated with thin alignment layers that are rubbed to establish a preferred orientation for the nematic molecules.

Our SLM is electrically-addressed. This means that we can modify the properties of liquid crystals pixels by applying a voltage signal to the SLM.

As the electric field is applied, the molecules tilt forward. It is this tilt that modifies the phase of the incident beam. The stronger the electric field, the greater the tilt and the greater the phase modulation



The SDE1024 is a liquid crystal on silicon [LCoS] SLM. LCoS is always reflective. Incident light travels through the liquid crystal cell and reflects off the back silicon wall.

Current Results

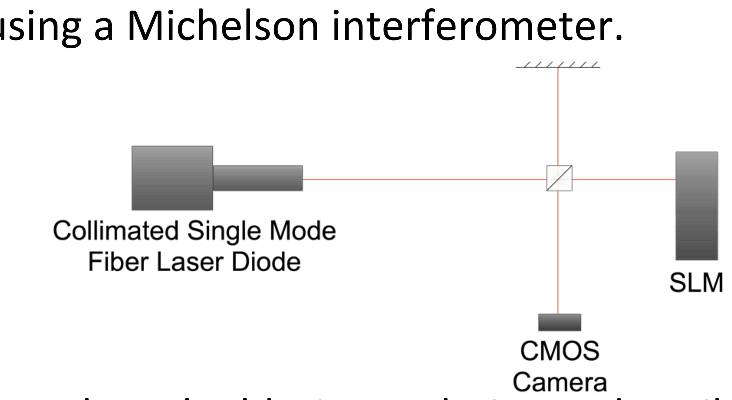
We have now learned how to communicate with and program our SLMs, but are still far from a complete understanding of the complex electro-optics involved.

We used Paint and MATLAB to control the display on the SLM. In room light, the SLM's bare active area looks like a shiny rectangle regardless of signal. We next placed a linear polarizer with its axis parallel to the long side of the SLM as suggested by the manufacturer. In ambient light, we observed a reverse video image of what was on the control computer.

We are now experimenting with laser illumination and other polarizer and analyzer configurations. We started by sending circular and rectangular apertures onto the SLM. While the expected diffraction patterns were present, their quality (contrast) was not very good due to limited diffraction efficiency.

Future Work

This project marks the first step in investigating the properties of the LTC's SLMs In the future, we hope to characterize the phase range of the device using a Michelson interferometer.



We will also explore the blazing techniques described by Bowman *et al.* [1] to increase the diffraction efficiency of our device.

References and Acknowledgements

[1] Bowman *et al.* "Optimisation of a low-cost SLM for diffraction efficiency and ghost order suppression." Eur. Phys. J. Special Topics 199, 149-158 (2011).

[2] Cambridge Correlators, "SDE1024 Spatial Light Modulator Kit", datasheet.

[3] D. Martin and S. O'Leary, "Spatial Light Modulator (SLM) Workshop," BFY Conference (2012).

[4] P.J. Collings, "Liquid crystals: nature's delicate phase of matter" (2nd ed.). Princeton, N.J.: Princeton University Press (2002).

[5] M. Bonomo, "Cambridge Correlator's low cost spatial light modulator," unpublished report (2013).

[6] M. Bonomo, "An Introduction to Spatial Light Modulators," unpublished report (2013).

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